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I have made with the sextant above described equally coincident observations for determination of latitude, but with these I do not think it necessary to trouble the Society.

*Ray Lodge, Maidenhead,* 1873, *November* 10.

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## *On a New Driving Clock for Equatorials.* By Lord Lindsay and David Gill, jun.

One of the most important adjuncts of the modern equatorial is the driving clock. Formerly the equatorial was merely expected to carry a small and light micrometer, and that with only moderate accuracy for a short time.

Now spectrum analysis and celestial photography demand a higher accuracy of rate, and that maintained for a considerable time.

Not only is it so, but this accuracy has to be attained under more unfavourable circumstances. Modern spectroscopes are of such considerable weight, and so unsymmetrical in shape, that it is difficult or impossible to maintain in all circumstances a perfect counterpoise of the equatorial.

From these considerations we endeavoured to realise the following conditions, in contriving a clock-motion for the great equatorial of the Dunecht Observatory.

1. A driving power four or five times as great as that actually required, so as to avoid failure when the balancing of the instrument is defective.
2. A rate of motion equal in accuracy to that of a good sidereal clock.
3. Maintenance of the same uniformity of rate under change of work to be done, twice as great as that to which the clock will be likely to be submitted.
4. An easy and rapid means of adjusting that rate and so avoiding delay in timing as much as possible.

The first of these conditions was easily attained by the employment of a large and powerful clock capable of being driven by a very heavy weight as in the accompanying sketch. The last three conditions are at once fulfilled by controlling a rotatory governor by a swinging pendulum, the latter being controlled electrically by the standard clock of the Observatory.

The Bonds in America, and the late Mr. Cooke of York, have both contrived clocks in which the rotation of a fan is controlled by a swinging pendulum, but in neither of these arrangements is the control perfect. In either construction a moderate increase of the driving weight will cause the clock to *run up* a certain amount before the control of the swinging pendulum is sufficient to overcome the increased tendency to gain. The effect of such

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a property is that under variation of resistance or power, the image of a star, though retained *near* the web during long intervals, will be found to oscillate from one side of the web to the other, a property fatal in photography, and troublesome in all other kinds of observation, except perhaps with a Heliometer, where such oscillations would be of no consequence, and the good general rate of the clock an advantage. After many experiments, which we shall not detail here, we have contrived the following arrangement, and the results of its adoption are so satisfactory that we are induced to think its description may be acceptable to the Society.

In fig. 1, *a k n* and *b l m* are steel bars (tipped with leather at the lower extremity) and sliding freely in the holes *k l m n*.

They would continually rub on the ring C D, which is attached to the axis of the governor balls, were they not sometimes kept from doing so by the arms *e f* and *g h*.

These arms are attached to the armatures of the electro-magnets A and B, and are pivotted at the points *p* and *q* respectively.

From inspection of the drawing, it is evident that in the normal condition, when no current is passed through A or B, the arm *e f* (carrying with it the bar *a k n*) will be raised by the action of the spiral spring $\alpha$, whilst the bar *b l m* will be allowed to rest on the ring C D, its support, the arm *g h* being removed by the spiral spring $\beta$.

This is the normal condition of the clock, and the governor is rated so as to keep very nearly true time when the bar *a k n* is raised from the ring C D, and when *b l m* rests upon it.

It is evident now, that we can retard the clock by lowering the bar *a k n*, so as to rest on the ring C D, or we can accelerate the clock by raising the bar *b l m* from its normal pressure on C D.

That is to say, to retard the clock-rate we must excite the electro-magnet A, and to accelerate it excite the electro-magnet B.

To send these currents of control, a Bain's Pendulum (fig. 2), P Q, is *driven* by currents from contact springs applied to the standard clock in the usual way.

A platinum point attached to the lower extremity of the pendulum at Q cuts through a globule of mercury R. As the arc of vibration of the pendulum is very large (viz. 7°), the contact with the mercury being very slight, and made at the lowest point of vibration, where the motion is most rapid, it may practically be considered instantaneous. This platinum point is in electrical connection with a terminal at P.

Upon a spindle of the clock, which revolves once a second, is fixed a vulcanite disc $\gamma\ \delta\ \varepsilon\ \sigma$. This disc is surrounded by a ring of silver, except at the four points $\gamma\ \delta\ \varepsilon\ \sigma$, where pieces of ivory are inserted and turned flush with the silver.

Upon the same axis, and on both sides of the disc $\gamma\ \delta\ \varepsilon\ \sigma$ are two smaller discs surrounded completely by silver. These

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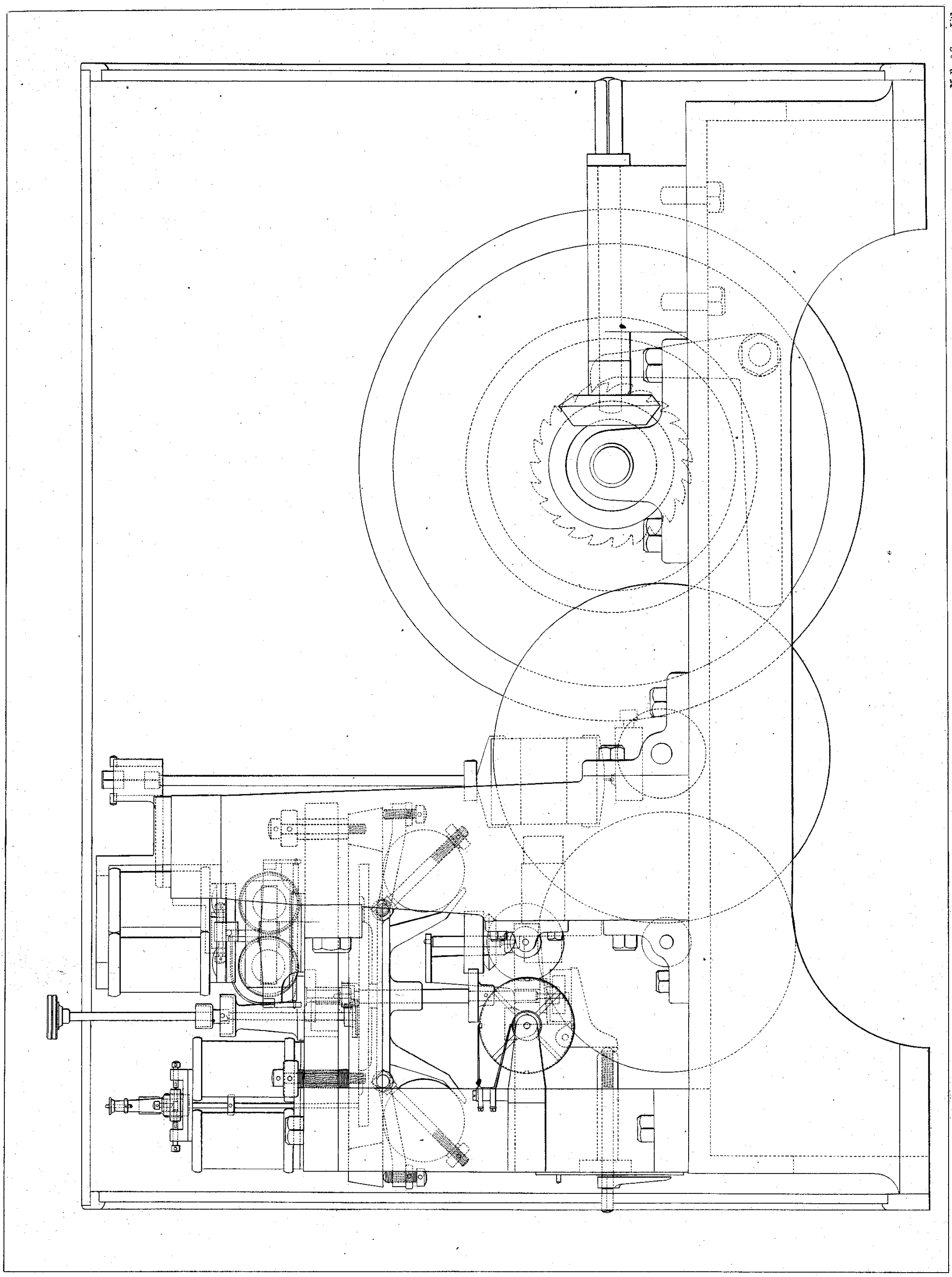

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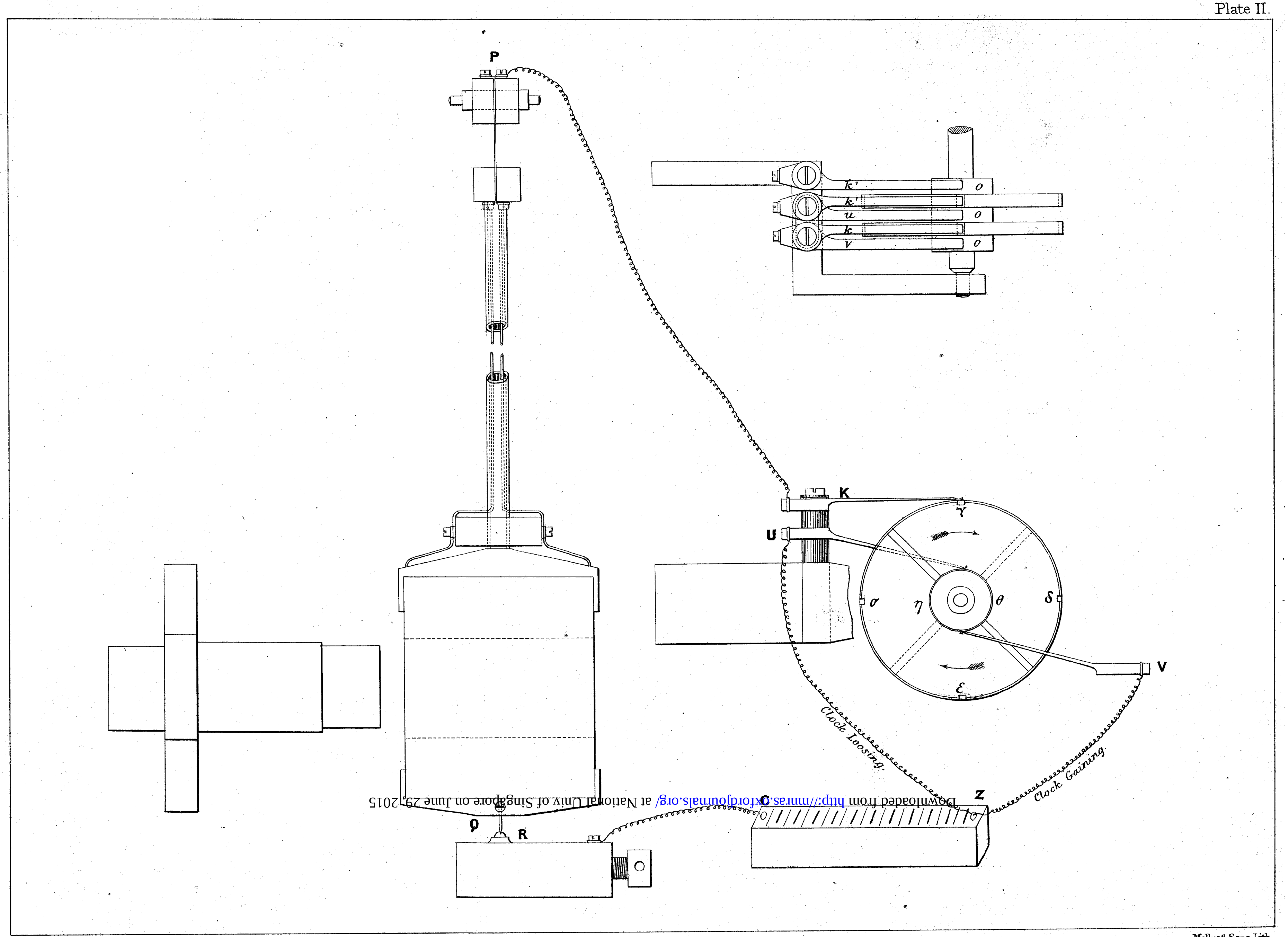
Plate II.



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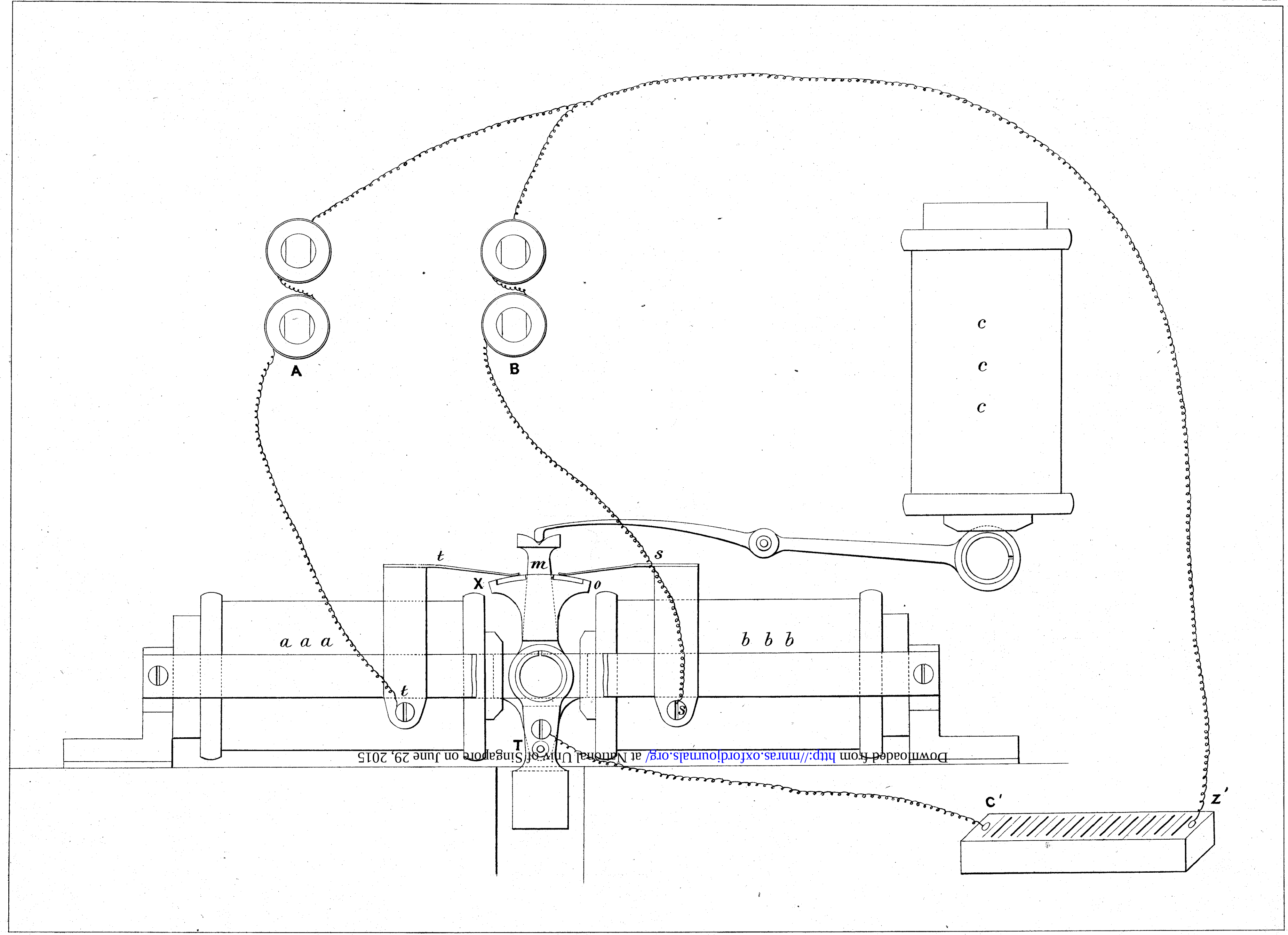

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discs are marked $\eta\ \theta$ in fig. 2, that on further side of $\gamma\ \delta\ \epsilon\ \sigma$, and invisible in the drawing, we shall call $\eta'\ \theta'$.

The segments of the large silver ring $\sigma\ \gamma$ and $\delta\ \epsilon$ are connected by a slip of silver with $\eta\ \theta$, and $\gamma\ \delta$ and $\epsilon\ \sigma$ are connected to the other disc $\eta'\ \theta'$ on the other side of $\gamma\ \delta\ \epsilon\ \sigma$.

Upon the large disc presses the spring K, and on the smaller discs $\eta\ \theta$, and $\eta'\ \theta'$ the springs V and U respectively.

Then if the spring K rests on the point $\gamma$ it is insulated, if on $\sigma\ \gamma$ or $\epsilon\ \delta$ it is in electric connection with the spring V, if on $\gamma\ \delta$ or $\epsilon\ \sigma$ it will be in connection with the spring U.

If now the spring K is connected to the terminal P, the mercurial reservoir of globule R to one terminal C of a battery (Plate II.), and the springs U and V to the other terminal, Z, of the same battery. If also the vulcanite disc revolves in the direction of the arrow heads, we see that when the instantaneous contact of the platinum point Q with the mercury at R occurs, at the instant that the spring K presses on the insulated point $\gamma$, no current whatever can pass—that is to say, no current can pass when the rotatory governor and swinging pendulum are in perfect sympathy.

If, however, during the next vibration of the pendulum the governor gains upon the swinging pendulum, then at the instant of next instantaneous contact the spring K will not rest on $\gamma$, but on some part of the segment $\gamma\ \sigma$ near $\gamma$, and a current will pass from C through R Q P K $\eta\ \theta$ V to Z, and similarly if the governor lose, K will then be on $\gamma\ \delta$ and the current will pass through $\eta'\ \theta'$ and U to Z.

That is, for *clock gaining* the instantaneous control current will flash through V Z, and for *clock losing* through U Z.

But *directly* these instantaneous currents would be useless for the purposes of control; accordingly a switch of the following description is employed, by which the accelerating or retarding effects are made to last during the entire second.

Plate III. *a a a* and *b b b* are electro-magnets, the helix of *a a a* being placed in the circuit of V Z, and that of *b b b* in the circuit of U Z.

The switch X *m o* T is pivotted at T.

Its surface X *m o*, on which the springs *t* and *s* rest, is insulated by ivory, except at *m*.

A second battery, C′ Z′, has one terminal connected to this switch, the other from Z′, through A to *t* and from Z′ through B to S.

If now the governor is fast of the pendulum we shall first have an instantaneous current through V Z, which excites *a a a*, attracts the switch X *m o*, which turns on a current to excite A, which lowers the arm *e f* (Plate I.), which lowers the bar *a k n* upon the ring C D, which retards the clock; and *vice versâ*.

As now described the switch would always either accelerate or retard, but there is a simple arrangement by which it is drawn into the centre, or neutral point, when there is no need for correction.

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This is simply another disc on the same spindle, the reverse of the disc $\gamma\ \delta\ \varepsilon\ \sigma$—that is to say, entirely insulated on the edge *except* at the points $\gamma$ and $\varepsilon$, which we shall call $\gamma'\ \varepsilon'$.

There is a spring like K, which we shall call K′, pressing on this disc, and when the instantaneous current takes place, when K′ is at $\gamma'$ it is made to pass through an electro-magnet *c c c*, and from the drawing (Plate III.), the manner in which the switch is brought to the centre will be evident.

The whole apparatus may appear somewhat complicated from this description, though, indeed, it is not so.

The power of control depends on the weight of the bars *a k n* and *b l m*, and the character of the friction surfaces, and can be almost indefinitely regulated, though, of course, when pushed too far, at the expense of uniformity of motion. It remains to be considered how far uniformity of motion is sacrificed by this control. All control must consist of oscillation, and all we can do is to reduce that oscillation to a harmless amount.

We have found from experiment that *without control* no change of work which the clock can be called upon to perform, that is, from driving only itself to driving the telescope, and that considerably and disadvantageously out of balance, affects the clock rate $\frac{1}{100}$ part, therefore the clock can commit no error in one second so great as the $\frac{1}{100}$ second.

We have adjusted the extreme limits of control to correspond to one second per minute; that is, that the clock may err $\frac{1}{120}$ second on either side of the point of sympathy in a second, and would be corrected during the succeeding second.

The effect is to produce a control so perfect that *no variation whatever* can be perceived on the second hand of the driving clock from that of the standard clock, during any number of hours, and no sensible oscillation of a star relative to the micrometer web under high powers.

It is no exaggeration to say that when the clock is driving the telescope the observer may add his own weight to the driving weight without affecting the accuracy of control.

The construction of the disc $\gamma\ \delta\ \varepsilon\ \sigma$, we have just described, permits the use of instantaneous currents at half-second intervals, and thus the power of control can be doubled, or the oscillation halved at pleasure. We have found the currents from a seconds pendulum however so entirely satisfactory that we have not as yet employed a half seconds pendulum.

The clock is the workmanship of Messrs. T. Cooke and Sons, York, and is most highly creditable to their firm.

We must conclude by expressing our obligations to them for the trouble they have taken, and the intelligent manner in which they have carried out our designs.

*The Observatory, Dunecht.*